Substitute Specification

Title of the Invention

A method for an immunoassay with a magnetic label and an apparatus for the same

Detailed description of the Invention

Field of the Invention

The present invention relates to an immunoassay and an apparatus for the same. More specifically, the present invention relates to a method and an apparatus for an immunoassay with a magnetic label and a SQUID.

Detailed Description of Invention

An immunoassay is a method to detect an antigen or an antibody (mentioned with the word "analyte" in this specification). For identification or measurement, a label is attached to antibody of an antigen-antibody reaction. Various labels and detection method have been proposed and are frequently used.

In particular, various optical methods are well known. In these methods, labels with light, fluorescence or color are used. However, optical methods have too short a sensitivity time for many applications.

As another method, a method using radioactive label is known. However, this method has problems concerning safety which limit its applicability.

Furthermore, there is methods with magnetic labels as a reemergence measurement or a magnetic relaxation method. However, in this method, grain size of the label influences the measured value seriously. Therefore, accuracy of measurement of this method is not stable.

On the other hand, a SQUID has recently been put to practical use. The SQUID comprises a circular current load and one or two Josephson junction(s) on the load. The SQUID has a very high sensitivity compared with a Hall device or a flux gate and is used as a magnetism sensor.

A new assessment method with magnetic label has been developed in accordance with the invention. In this method, it is expected that labels can be detected by a SQUID with high accuracy. However, there is no known practical method to use a SQUID in this context. Magnetic labels have to be magnetized for detection by a SQUID. However, a strong magnetic field of dozens of gauss is necessary for the label to be magnetized.

On the other hand, a SQUID has a very high sensitivity. Therefore, a serious problem occurs in that a SQUID receives the effects of the magnetic field of magnetization means and the desired measured value of the label changes.

Furthermore, an analyte is actually treated with a prepared slide. But, a strong magnetic field magnetizes the prepared slide. Therefore, it is difficult to detect only a label.

Summary of the Invention

The present invention provides a method for an immunoassay with magnetized label and SQUID, which comprising following processes;

(1) an analyte is labeled with a magnetic material label to detect antigen-antibody reaction,

(2) the magnetic material label is magnetized by a magnetic field,

(3) the magnetized magnetic material label detected by a SQUID which detect a magnetic field having right angle to the magnetic field.

In method of the present invention, labels are magnetized and detected by a SQUID. According to a preferable embodiment of the present invention, the magnetic field for magnetization is a static magnetic field.

According to another preferable embodiment of the present invention, an analyte is inspected while moving parallel to the flux forming the magnetic field inside the detection region of the SQUID. Then, the SQUID detects a variation of magnetic field occurred by the moving labels magnetized in particular direction.

At the same time, the present invention contains an apparatus to execute the method provided by the present invention. The apparatus comprises a magnetic field generation means that generates a magnetic field to magnetize the labels. The apparatus comprises a SQUID that measures the magnetic field.

It is preferable that the apparatus comprises a transportation means which moves the analyte with the magnetized label parallel to the magnetic field generated by the magnetic field generation means.

Furthermore, the apparatus preferably comprises magnetic field compensation means. The compensation means generates a magnetic field parallel to the detection direction of the SQUID. The magnetic field for compensation cancels the magnetic field is at a right angle to the magnetic field for magnetization. Because, the magnetic field for magnetization contains a component that has a right angle to the desired magnetic field and the SQUID has very high sensitivity to detect the component.

According to the preferable embodiment of the present invention, the SQUID is formed of an oxide superconducting thin film having a high critical temperature. By the way, the sensitivity of a SQUID is proportional to the third power of the distance between the SQUID and the analyte. The oxide superconducting materials can be used with a small cooling-systems. The use of the oxide superconducting materials is advantageous in this point.

It is an important characteristic of the present invention that the magnetic field for magnetization is at a right angle to the magnetic field detected by the SQUID. That is to say, in a prior art, the magnetic field for magnetization and the magnetic field detected are parallel to each other. Therefore, the SQUID also detects the magnetic field for magnetization.

On the contrary, in apparatus of the present invention, the magnetic fields are arranged at right angles to each other. The SQUID detects a flux at a right angle to its circular current load and never detects a flux parallel to the circular current load. Therefore, in an apparatus provided by the present invention, the SQUID does not detect the magnetic field for magnetization. In a method using a SQUID of the prior art, a magnetic field for magnetization is an alternative and a noise is offset by using a lock in amplifier.

According to a preferable embodiment of the present invention, a static magnetic field can be used. Because, the static magnetic field can be easily compensated by simple means with a solenoid.

However, because the SQUID has very high sensitivity, even using the magnetic field for compensation will not compensate the magnetic field for magnetization perfectly. Then, according to a preferable embodiment of the present invention, the SQUID detects a variation of the magnetic field. This variation of magnetic field occurs because of motion of the magnetized label in the detection field. This variation itself is not influenced by the magnetic field of the perimeter.

The above and other objects, features and advantages of the present invention will be apparent from following description of preferred embodiments of the invention with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a perspective view showing a principle of the method provided by the present invention.

Figure 2 is a sectional view showing a basic construction of the apparatus provided by the present invention;

Figure 3 shows labels and antibodies.

Figure 4 is a graph showing an output signal of the SQUID.

Figure 5 is a graph showing a relationship between concentration of an antibody and the output of the SQUID.

Figure 6 shows the antigen-antibody reaction labeled with a magnetic label.

Figure 7 is a graph showing measured resultant in comparison with a resultant by a prior art.

Description of the Preferred embodiments

In the method of the present invention, as shown in the figure 1, an analyte 2 supported on a support 1 with label is magnetized at first by a magnetic field shown with arrow A parallel to surface of the support 1, and is detected by a SQUID 3.

The SQUID 3 comprises a ringed current load that is arranged parallel to the surface of the support 1. Therefore, a magnetic flux detected by the SQUID 3 is at a right angle to the surface of the support 1. Namely, a region under the SQUID 3 becomes a detection region of the SQUID 3. On the contrary, the magnetic field for magnetization is parallel to the surface of the support 1. Therefore, the SQUID 3 has substantially no sensitivity to the magnetic field A for magnetization.

Furthermore, the support 1 moves parallel to the magnetic field A with fixed velocity X. When the analyte 2 passes into the detection region of the SQUID 3, the magnetic field of the detection region changes and the SQUID 3 detects the change of the magnetic field. By the way, at the same time, the support 1 is magnetized too. Therefore, it is preferable that the length L and the width W of support 1 are sufficiently large so that the detection region is initially met by support 1 while no analyte 2 is in the detection region.

The method mentioned above can be executed with an apparatus shown by figure 2. This apparatus comprises magnetic shields 101 a, 101 b, SQUID 103, coils for magnetization 106 a, 106 b, a compensating coil 107 and a transportation means 105.

The magnetic shields 101a, 101b surround the whole apparatus and the measurement is done within the magnetic shields 101 a, 101 b. SQUID 103 is taken into a container 102 filled with liquid nitrogen 102a and arranged horizontally. The magnetization coils 106a, 106b are placed parallel mutually and have right angle to the SQUID 103.

The compensating coil 107 is placed in the lower part of the SQUID 103 and arranged parallel to the SQUID 103. Any vertical component of the magnetic field generated by the magnetization coils 106 a, 106 b is canceled with the magnetic field formed by the

compensating coil 107. Then the magnetic field inside the detection region includes substantially only horizontal flux.

The transportation means 105 comprises an arm that moves to X-Y direction in horizontal and conveys a sample 104. Transportation means 105 can carry sample 104. The sample 104 is inserted into the magnetic shields 101 a, 101 b from the side by the transportation means 105 and passes inside the coil 106 a, 106 b. Then the sample 104 is magnetized by the coil 106a, 106b. Next, the sample 104 arrives the detection region.

We assembled the apparatus mentioned above with elements below.

The SQUID 103 was made of patronized oxide superconducting thin film on a $SrTiO_3$ substrate. The magnetic shields 101 a, 101 b were made of Permalloy.

Sample 104 was supported by a glass plate having dimension of 20 mm *80 mm as a support 1. The glass plate is produced by Nalge Numc International company (USA). The glass plate passed 1.5 mm lower part of the SQUID.

We prepared two kinds of antibody for preparation samples.

One is a A type antibody named "MACS" provided from Miltenyi Biotec company (Germany). The MACS is a particle of gamma-Fe_2O_3 14a coated by a polymer 14b and antibody 14 sticks to the polymer 1.4b as shown in figure 3 (a). Average particle diameter of the A type antibody is 50nm and weight of A type antibody is approximately $4*10^{-16}$g.

Another one is a B type antibody named "dynabeads" provided by Dynal company (Norway). Plural magnetic material ultrafine particle 14a is contained in a polymer graining 14c as shown in figure 3(b) and an antibody 14 sticks to polymer 14c. Average particle diameter of B type antibody is 4.5 μm and weight of B type antibody is approximately $14.3*10^{-12}$ g.

Example 1

Sample mentioned above was inspected with apparatus shown by figure 2. We used a decentralized liquid of A type antibody (rat / anti mouse Ig G1). In stock solution, concentration was indicated 0.2 mg/ml and Average particle diameter was 50nm, 5.2 g/cm^3. According to the inference, weight of magnetic material particle is $3.4*10^{-16}$ g and the particle is contained during stock solution at $5.8*10^{11}$ / ml. Then we diluted the stock solution with PBS into 1/10 and put it on the glass plate as an analyte. The sample on the glass plate occupied a region with 2 mm diameter and its amount was 2 μ liter. Accordingly,

this sample contains $1.2*10^8$ magnetic particles and general mass of the magnetic particles is 40ng.

The acidity of magnetic field for magnetization was $8*10^{-4}$T and the drift speed of analyte was 8 mm per second. Output signal of the SQUID 103 was recorded through a band-pass filter having range from 0.1 Hz to 5 Hz. Recorded output signal is shown in figure 4.

As shown in the figure 4, extremely clear variation of the magnetic field was recorded. Sensitivity of SQUID depends on the distance between a SQUID and an analyte. Therefore, the sensitivity of the apparatus can be regulated by the distance.

Example 2

A relation between the concentration and the detection resultant of the sample is shown in figure 5.

Circles plotted in the figure 5 show determination resultant of the sample that was labeled with the A type antibody and diluted with PBS in various concentrations. Rectangles plotted in the figure 5 show determination resultant of the sample that was labeled with the B type antibody and diluted with PBS in various concentrations. The sample was rat / anti mouse Ig G1 and diluted with PBS. As shown in the figure 5, high correlation between the detected magnetic signals and the quantity of the labeled antibody can be seen for the both cases.

Example 3

Another Sample was prepared. As shown in figure 6, in this sample, antigen 11 is fixed by a first antibody 12 to the support 1. Then, a second antibody 13 sticks selectively to the antigen 11. Furthermore, a third antibody 14 labeled with magnetic material 14a sticks to the second antibody 13. The SQUID detects the magnetic material 14a.

The sample put on the region having a diameter of 8 mm on the support. At first, we fixed a "mouse / anti humans interferon β monoclonal antibody (YMASA company, JAPAN) as the first antibody 12 in region. Next, we let a humans-interferon B as the antigen 11 react to the region at 37 degrees Centigrade for 3 hours. Then we prepared a rabbit-anti human interferon β / polyclonal antibody (Bio-Rad company, U.S.A.) as second antibody 13 and goat / anti rabbit ig G as the third antibody 14. The Goat / anti rabbit Ig G has been labeled with a magnetic material ultrafine particle and was reacted to the region at 37 degrees Centigrade for 1 hours.

Determination effect by measuring the sample above is shown in figure 7. The determination resultant is plotted with circles. At the same time, rectangles are plotted in the figure 7. These rectangles means resultant surveyed by an optical method according to a prior art, ELISA system type II by Biotrak company. In this method, at first, an antibody is reacted to an antigen and next, a stroma is added them. Then the coloring antibody can be detected. For reference, the same goat / anti rabbit Ig G was used as an antibody.

As shown in the figure 7, this optical method shows good correlation with specified field where the concentration is more than 1 unit / ml. However, the correlation becomes worsen with lower field than the specified field. On the contrary, a good correlation is maintained by the method of the present invention. Then we understood the method of the present invention is clearly superior to the prior art. As explained, the method of the present invention can realize high sensitivity and high accuracy. Furthermore, a magnetic material can be smaller than 600pg, therefore, the sensitivity of the present invention should be improved easily.

Abstract

The present invention relates to an immunoassay and an apparatus for the same. A method of the present invention comprises following processes; (1) an analyte is labeled with a magnetic label to detect antigen-antibody reaction, (2) the magnetic material label is magnetized by a magnetic field, (3) the magnetized magnetic material label detected by a SQUID which detect a magnetic field at right angles to the magnetic field.